SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

Preliminary Draft Staff Report for

PROPOSED AMENDED RULE 1149 – STORAGE TANK AND PIPELINE CLEANING AND DEGASSING

Dated: December 2007

Deputy Executive Officer
Planning, Rule Development, and Area Sources
Elaine Chang, Dr.PH

Assistant Deputy Executive Officer
Planning, Rule Development, and Area Sources
Laki Tisopulos, Ph.D., P.E.

Planning and Rules Manager
VOC Rule Development
Larry M. Bowen, P.E.

Author:	Mike Morris	AQ Specialist
Reviewed by:	Ed Muehlbacher, P.E.	Program Supervisor
	Bill Wong	Senior Deputy District Counsel
Contributors	Roger Christopher	Supervising AQ Inspector
	Hassan Namaki	AQ Engineer II
	Eugene Teszler	AQ Specialist
	Sam Vergara	Supervising AQ Inspector

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EXECUTIVE OFFICER:

BARRY R. WALLERSTEIN, D.Env.

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EXECUTIVE SUMMARY

Rule 1149 – Storage Tank Cleaning and Degassing was originally adopted by the South Coast Air Quality Management District (AQMD) on December 4, 1987 and subsequently amended on April 1, 1988 and July 14, 1995.

Rule 1149 applies to VOC emissions from cleaning and degassing operations in large aboveground petroleum storage tanks at petroleum refineries and terminals and small underground gasoline storage tanks. The current regulation requires vapors contained in storage tanks to be vented to a control device for a pre-determined length of time or to be displaced by a liquid into a control device.

The proposed rule amendments will instead require a vapor concentration of 5,000 ppmv, measured as methane, to be met before allowing the vapors to be vented to atmosphere. This proposed standard will better capture emissions from sludge and product residual remaining in the tanks. Liquid balancing, or any other technology that achieves the proposed standard will be allowed.

The proposed rule amendments will also expand its applicability to small above ground gasoline storage tanks, pipelines and large storage tanks previously exempted because of lower vapor pressure products. Furthermore, the proposed rule will streamline the notification process and clarify requirements for vacuum trucks and containers used for storing liquid and sludge removed during the cleaning process.

If approved, the proposed rule amendments would fully implement control measure FUG-04 in the 2007 Air Quality Management Plan.

As proposed, the rule would reduce VOC emissions by 1.25 tons per day at an estimated cost of $5.5 million dollars. The overall cost per ton of VOC reduced by the proposed amendment is estimated to be $12,055.

Many degassing operations routinely achieve in practice the proposed requirements set forth in the proposed rule. California Code of Regulations, Title 8 - General Industry Safety Orders has strict restrictions for entry into confined spaces with hazardous atmospheres such as petroleum storage tanks. In order to avoid the restrictions, many facilities vent the vapors contained in the storage tanks into a control device until the tank interior is no longer considered a hazardous atmosphere and the proposed rule requirements would be met. Additionally, concern for nearby schools and residences as well as the potential for Rule 402 – Nuisance violations keeps facilities from discharging odorous VOC emissions.

REGULATORY BACKGROUND

In 1987, Rule 1149 – Storage Tank Cleaning and Degassing was adopted to reduce VOC emissions from degassing operations of stationary storage tanks. The Standard Industrial Classification codes for applicable facilities include crude petroleum and natural gas (SIC code 1311), paints, varnishes, lacquers, enamels, and allied products (SIC code 2851), cyclic organic crudes and intermediates, and organic dyes and pigments (SIC Code 2865), industrial organic chemicals, not elsewhere classified (SIC code 2869), petroleum refining (SIC code 2911), special warehousing and storage, not elsewhere classified (SIC code 4226), crude petroleum pipelines (SIC code 4612), refined petroleum pipelines (SIC code 4613), chemical and allied products, not elsewhere classified (SIC code 5169), petroleum bulk stations and terminals (SIC code 5171), and automotive dealers and gasoline service stations (SIC code 5541).

At the time of adoption, staff estimated that 800 floating roof tanks, 213 fixed roof tanks and 33,600 underground storage tanks (UST) located at petroleum refineries and terminals, chemical plants and gasoline stations would be subject to the rule. Based on each tank being degassed once every ten years, an estimated 0.4 tons per day were expected to be controlled from floating and fixed roof tanks and another 0.3 tons per day were to be controlled from USTs.

The premise of the rule has been a differential equation describing the change in concentration:

$$dC/dt + QC/V = 0$$

where dC/dt is the change in concentration in the tank over time, Q is the flow rate, C is the final concentration and V is the volume.

The solution to the equation:

$$C = C_o\, e^{-(Qt/V)}$$

when the final concentration is 10 percent of the initial concentration, or $C = 0.1C_o$, gives:

$$0.1C_o = C_o\, e^{-(Qt/V)}$$

$$\text{or } 0.1 = e^{-(Qt/V)}$$

Thus theoretically, to get a 90 percent reduction in emissions, then $t = 2.3V/Q$. Or in other words, if a tank were to be degassed to a control device for a period of time equal to 2.3 volume turnovers, 90 percent of the emissions would be controlled. The use of the equation makes a key assumption which is that the storage tank has no product or sludge remaining in the tank when the degassing begins.

In 1995 the rule was amended to remove ambiguities in rule language relating to business and regulatory practices. Specifically, the clarifications included alteration of notification procedures and confirming that USTs to be degassed must be controlled and done in a timely period even if it is removed from the ground. It also intended to extend the application of the rule to storage tanks that were undergoing product changes by adding the term “cleaning” to the applicability of the rule.

The staff report in 1995 also noted that the number of USTs degassed was significantly lower then estimated in 1987. Despite only 30 percent of the original estimated USTs being degassed annually, the report concludes that the corresponding total emission reductions from the rule would not change significantly. This was explained by demonstrating that more than twice the emissions predicted in 1987 were being controlled by venting emissions from product and sludge removal, rinsing and degassing instead of degassing alone. While only applied to USTs, this approach is noteworthy because it deviates away from the theoretical calculations that the original emission inventory was derived from. A similar approach will be used in this report to determine the emission inventory and potential emission reductions.

AQMD Rules 463 – Storage of Organic Liquids and Rule 1178 - Further Reductions of VOC Emissions from Storage Tanks at Petroleum Facilities are closely related to this regulation. In particular, Rule 463 specifies emptying and refilling procedures that occur just before and after degassing operations. For example, while a tank was being drained of product, Rule 463 would apply and require the draining to be continuous. Once draining was complete, Rule 1149 would apply until product was reintroduced into the tank at which point Rule 463 would once again

apply. While there are no vapor concentration limits directly associated with emptying or refilling, Rule 463 does have a vapor leak limit of 1,000 ppmv, expressed as methane. Rule 1178 applies to larger storage tanks at petroleum facilities and establishes additional control requirements and specifications to those included in Rule 463.

The Office of Pipeline Safety is the primary federal agency regulating pipelines. There are provisions for maintaining pipelines and reporting and repairing leaks, but no provisions for controlling vapors from leaks or degassing operations. In California, the Office of the State Fire Marshall, Pipeline Safety Division regulates the safety of hazardous liquid transportation pipelines. The office inspects, tests and investigates to ensure compliance with state and federal pipeline safety laws. Like the federal government, the state has provisions for maintaining pipelines and reporting and repairing leaks, but no provisions for controlling vapors from leaks or degassing operations.

OPERATIONAL BACKGROUND

Vapors are created whenever there is a space between the liquid level and the roof of a storage tank. The more volatile (higher vapor pressure) the liquid, the more vapors are present. Large tanks with volatile liquids like crude oil or gasoline can generate thousands of pounds of VOC vapors. These vapors will be emitted if the tank is opened to atmosphere for maintenance, repairs or removal. Vapors can also be emitted while the roof of a floating roof tank is allowed to rest on its support legs during a product change. All these types of operations are subject to the provisions of Rule 1149. The vapors will also be emitted when the tank is refilled and the vapor space is eliminated. Emissions generated from tank filling operations are covered under Rules 463 - Organic Liquid Storage and 1178 – Further Reductions of VOC Emissions from Storage Tanks at Petroleum Facilities.

Facilities limit emissions from repairs, maintenance activities, product changes and during refilling by controlling degassing operations. A product change occurs when a tank is used to temporarily store a product such as crude oil or gasoline. When the product is purchased, the entire tank is pumped to the purchaser. That leaves the tank empty, but filled with vapors and the roof resting upon the support legs, open to atmosphere.

The degassing process consists of several procedures intended to leave the tank free of product, sludge and vapors. The bulk of the product in the tank, if any, is pumped into another tank. A vacuum truck then sucks out the residual product. At this point the tank is largely free of liquid but may contain a relatively small amount of liquid, some sludge and is filled with vapors. Depending on the amount of sludge, the tank may be cleaned and rinsed before degassing (purging the gas) begins. Purging the gas is generally done by sucking the vapors out of the tank or displacing the vapors with a lower vapor pressure product. Because of the provisions in Rule 1149, the vapors purged are vented to a control device or vapor recovery system. These controls devices are typically portable engines or thermal oxidizers that combust the vapors as fuel. Because the vapor concentration may fluctuate substantially during the process, propane is used as an auxiliary fuel to ensure that enough fuel is available to maintain combustion at all times.

Other techniques used to control vapors from storage tanks include liquid balancing and water or chemical washing or rinsing. Liquid balancing consists of draining the tank until just prior to the floating roof resting on its support legs. The tank is then filled with a low vapor pressure liquid, allowing the chemicals to mix, and repeating until the desired vapor pressure of the liquid blend is reached. Because there is no vapor space created during the mixing process, no vapors are

created. When the tank is finally completely drained, only vapors from the low vapor pressure liquid created remain in the storage tank.

Water or chemical washing or rinsing cleans the tank of product and residual sludge thus diminishing the amount of VOC vapor concentration in the tank. The storage tank remains closed or air tight during the cleaning process. Water or a chemical is added to the tanks, sometimes with a high pressure jet. The sludge created is pumped out and, at a minimum, further emissions from sludge and product residual will be minimized. Once the tank has been degassed, the tank will be opened to ventilate the remaining vapors. This ventilation can be done by opening a vent and pulling fresh air into the tank or using a blower to force the vapors out of the tank. There may be a final cleaning and rinsing step to remove any last remnants of sludge.

If the tank is taken out of service for maintenance, repair or removal, California Code of Regulations Title 8 Section 5157 prohibits entry into a hazardous atmosphere which includes flammable gas, vapor or mist in excess of 10 percent of its lower explosive limit (LEL). A significant number of tanks degassed continue venting vapors to the control device until the 10 percent LEL is met. It should be pointed out that as currently written, a company can comply with Rule 1149 by purging the vapors to a control device for a time equal to 2.3 air exchanges and then releasing the remaining vapors even though product, sludge and/or a hazardous atmosphere remains in the tank.

Storage tank operators minimize the amount of vapors created by utilizing floating roof tanks. These types of tanks have a roof that float on top of the liquid product. Unlike fixed roof tanks where the roof remains on the top of the structure (see Figure 1), the floating roof level correspondingly changes with the level of the liquid to prevent any space being created between the liquid level and the roof (see Figure 2). The roof can remain floating on the liquid from the total capacity of the tank all the way down to about six feet from the bottom of the tank. At that point the floating roof rests on its support legs and vapor space is created. When on the support legs, the space is open to atmosphere but is only about one tenth the volume of a fixed roof tank with the same capacity because the vapor space is about six feet while tank height is closer to sixty feet. A typical practice is to store more volatile liquids in floating roof tanks while heavy liquids to be stored for longer periods would more likely be sent to a fixed roof tank.

Pipeline degassing is conducted in a similar manner to degassing a fixed roof tank with two noteworthy differences. First, the pipeline can be sealed at each end so as to only allow vapors from the particular section being tested, maintained or replaced. These vapors can easily be captured and controlled under normal circumstances. Second, an inert gas, such as nitrogen, is often introduced at very high pressure to keep product and flammable vapors away from the work area. As the pipeline is refilled with product, the high pressure inert gas must be released. At the interface between inert gas and product there is some small amount of vapor mixing that potentially could emit a small amount of VOC. However, trying to control the small amount of VOC would require capture and control of a high pressure gas creating an unsafe condition.

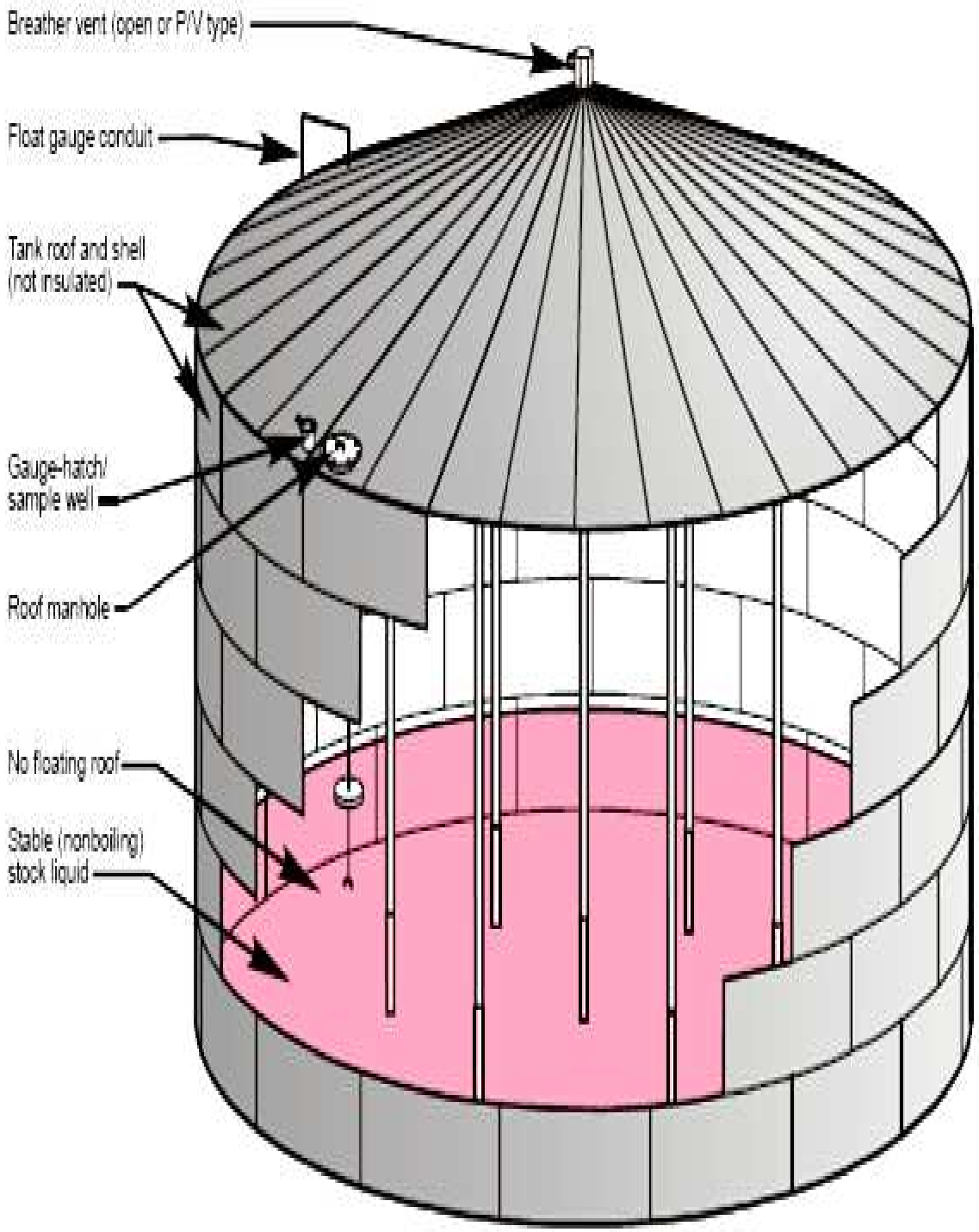

Figure 1 – Fixed Roof Tank (From AP-42, Section 7.1, U.S. EPA

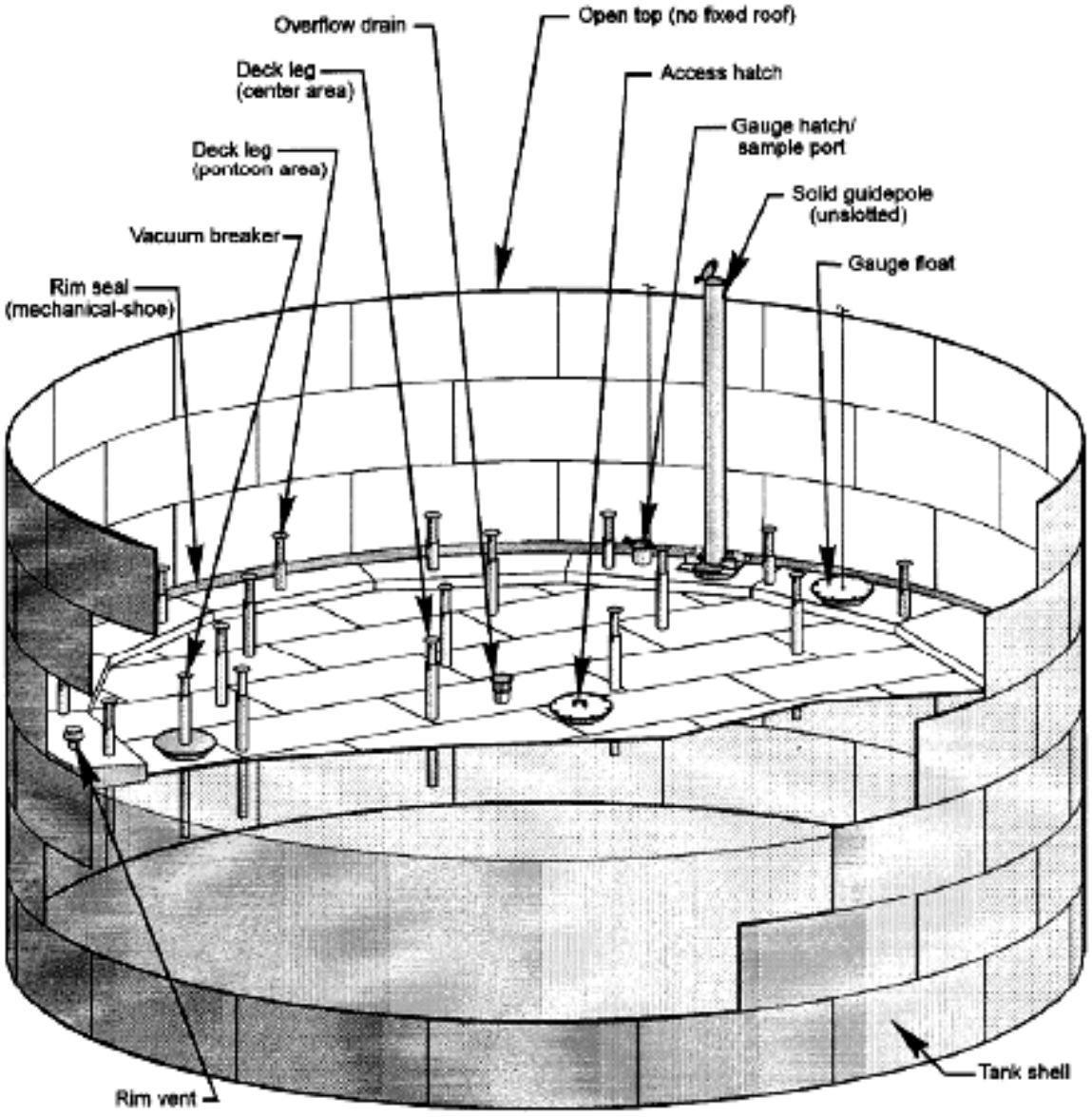

Figure 2 – Floating Roof Tank (From AP-42, Section 7.1, U.S. EPA)

PROPOSED AMENDMENTS

Staff proposes to amend Rule 1149 as follows:

- Remove time and equipment requirements in (c)(5) and (c)(6) and replace with a vapor concentration requirement of 5,000 ppmv, measured as methane. The concentration must be met for at least one hour after degassing has been completed. This will prevent tanks with excess product residual or sludge from being opened prematurely. The proposed vapor concentration standard conservatively translates to a ten percent LEL already met by many degassing operations. The vapor concentration standard will capture the

majority of emissions created by product residual and sludge. Any technique, including liquid displacement, is allowed as long as any vapor displaced is routed to an approved vapor recovery system and the vapor concentration standard is met. In most instances, companies will utilize the same techniques currently in use but be required to do so for a longer period of time. However, new innovations and processes may be developed to meet the proposed standard. By establishing a standard as opposed to one or more control techniques, the rule provides flexibility to industry to apply technological advances.

- Extend the applicability of the rule to pipeline and to more above ground storage tanks (see Table 1).

Table 1 – Proposed Changes to Storage Tank Applicability

Reid Vapor Pressure	Typical Products	Current (gallons)	Proposed (gallons)
3.9 psi	Gasoline	19,815	500
2.6 psi	Crude	39,630	26,420
0.5 psi	Toluene	N/A	100,000

- Lower the VOC vapor concentration of a Vapor Leak from 10,000 ppmv to 5,000 ppmv. This will make the Vapor Leak standard consistent with the vapor concentration standard. It will require all the hoses, fittings and connections to meet the same standard the tank or pipeline is required to meet. It differs from the requirements of "Vapor Tight" in Rule 463 (1,000 ppmv) because product and residual is being removed from the tank or pipeline instead of "stored" to which Rule 463 applies. The proposed rule will also remove the test method from the definition and place it in the Test Methods section.
- Require floating roof tanks that are emptied for product changes to degas while the floating roof rests on its support legs. While the roof rests on its support legs, the seals lose integrity and vapors may escape to atmosphere. Product changes occur when crude oil is received from overseas and when products are sold from one company to another. This will address a common situation and codifies an enforcement policy.
- Require vacuum trucks that remove product residual and sludge from pipeline and storage tanks subject to the rule to exhaust vapors into a control device. Vacuum trucks are not designed to store vapors or control vapors themselves. When vacuum trucks pump product into their tanks, vapors are created and may escape to atmosphere if not properly controlled.
- Limit the exhaust concentration of control devices used to 500 ppmv, measured as methane. In many cases the vapor concentration in a tank can be greater than 100,000 ppmv. Ninety percent control would allow 10,000 ppmv to escape and even 99 percent control would allow 1,000 ppmv to escape. This will set a stringent, yet achievable standard that is consistent with other AQMD rules.
- Require that product residual and sludge taken from pipeline and storage tanks subject to the rule is stored in closed containers free of liquid and vapor leaks. This will reduce emissions that might occur while the waste material is waiting further processing. Prior

to the completion of degassing operations, all waste shall be stored in closed containers. Once degassing has been completed per the proposed rule requirements, any remaining sludge should be mostly VOC free and can be transferred into storage bins or other appropriate waste containers.

- Eliminate the emergency notification requirements and shorten the notification period and duration as well as eliminating the need for authorization. The notification procedure will be streamlined requiring between two hours and two days notification before degassing takes place. It is common currently to have several duplicate notifications for a single degassing event. In addition, emergency degassing operations are delayed while waiting for the emergency to be approved by an authorized agency officer allowing uncontrolled VOC emissions into the atmosphere. Most emergency situations will take longer than two hours to get degassing equipment on-site. In the rare instance where an emergency occurs and degassing equipment is available in less than two hours, the facility may utilize Rule 430 – Breakdown Provisions. The new notification procedures will allow more flexibility to affected sources and improve the accuracy of the notifications.
- Delete the definition for Underground Storage Tank. The limits for underground were previously different and thus necessitated defining the difference between the tanks. The limits are now the same and differentiation is no longer necessary.
- Add a definition for Natural Gas and exempt natural gas pipeline from the provisions of the rule. Natural gas is comprised mostly of methane which is not considered VOC.
- Revise the definition of Volatile Organic Compound to refer to Rule 102 to be consistent with other VOC rules.
- Exempt small diameter pipeline and small lengths of pipeline depending on the vapor pressure of the liquid it previously contained. The pipeline exemptions are based on the exemptions for storage tanks with similar volumes. Thus a 500 gallon gasoline storage tank is roughly equivalent to a 100 foot length of pipeline containing gasoline. Similarly, 0.25 miles of crude pipeline is roughly equivalent to a 26,420 gallon crude oil storage tank.
- Remove the exemption for storage tanks exempted in Health and Safety Code Section 25281. Most of the tanks exempted under Health and Safety Code Section 25281 will not be subject to the proposed rule because they contain low vapor pressure products. However, gasoline tanks on farms with capacities greater than 500 gallons will now be subject to this rule. Gasoline tanks on farms with capacities greater than 1,100 gallons were already subject to the rule.

EMISSION INVENTORY

The original emission inventory generated in 1987 estimated that uncontrolled emissions subject to Rule 1149 were 1.26 tons per day. Above ground storage tanks (AST) accounted for 0.5 tons per day while USTs accounted for the remainder. Based on the theoretical reduction from degassing over 2.3 air exchanges, the rule was expected to reduce emissions by 0.7 tons per day, with 0.4 tons per day being reduced from ASTs. The 1995 rule amendment made some new assumptions regarding how to calculate UST emissions but did not change the uncontrolled or expected reduction emission inventories.

However, over the 18 years since the initial emission inventory was generated, tank types, capacities and frequency of degassing incidents have changed. Initially, all tanks were assumed to be degassed once every 10 years and estimates were made to calculate the volume required to be degassed. The initial emission inventory was based on floating roof tanks having 56,991 cubic feet to be degassed. The average fixed-roof tank degassed had a volume of 125,214 cubic feet to degas. 101 tanks would be degassed each year (80 floating and 21 fixed). Assuming complete saturation of gasoline or crude oil, this accumulates to 0.5 tons of VOC per day.

Notification provisions in the rule have provided AQMD with detailed information including location, tank capacity and tank contents. Except in the relatively uncommon situation where a tank is degassed using liquid displacement, each time a tank is to be degassed by the facility or by a third party contractor, the degasser will notify the AQMD. With this information, staff has been able to refine the estimates of the volume, contents degassed and frequency of degassing events. Most importantly, the notification data shows that the ASTs are degassed at more than three times the frequency predicted. While most ASTs still are degassed every ten years or so for periodic repair and maintenance activities, some ASTs are degassed on a weekly basis because they are used primarily for product changes.

A limitation, however, is the lack of information regarding whether the AST was a floating roof or fixed roof type. This is important because for equal capacity tanks, the volume degassed in a floating roof tank is approximately one tenth that of a fixed roof tank. For example, a typical tank height is approximately 60 feet. It would be necessary to degas the entire 60 feet of a fixed roof tank while a floating roof tank would only need to degas about six feet of space. Staff conducted an assessment to determine the frequency of degassing when comparing floating versus fixed roof tanks. Industry was consulted, staff made site visits and compared notifications with tank rosters. It is estimated that 90 percent of all AST degassing operations are for floating roof tanks.

Table 2 summarizes the notification data submitted to the AQMD between 2004 and 2006.

Table 2 – Notification Data Summary

Above Ground Storage Tanks	**2004**	**2005**	**2006**	**3 yr ave.**
# AST degassed	295	268	421	328
Ave capacity AST (cubic feet)	765,335	732,731	720,202	739,422
Total volume degassed (million cubic feet)	44.7	38.9	60.0	47.9
Total uncontrolled emissions (tpd)	1.7	1.4	3.1	2.1

The summary data shows that an average of 328 ASTs with an average capacity of 739,422 cubic feet were degassed annually. The volume was calculated by using the volume reported and assuming that only 10 percent of the tanks were fixed and would degas the entire volume. For the remaining 90 percent of the ASTs, only about one-tenth of the volume reported would require degassing. This is because the roof of the floating roof tanks "floats" on the liquid in the tank until the tank liquid level is lower than the support legs which are generally about 6 feet tall.

Using the ideal gas law methodology, the uncontrolled average annual emission inventory estimate from ASTs would be 2.1 tons per day. The vapor pressure and molecular weight were determined from the product in the tank. The ideal gas law methodology assumes that complete saturation has had time to occur and that there are no additional sources of emissions. It is calculated as follows:

$$E = (VP / 14.7 \text{ psia}) * (MW / 379 \text{ ft}^3) * V$$

Where

E = emissions, lb
VP = vapor pressure, psia
14.7 psia is atmospheric pressure under standard conditions
MW = molecular weight, lb/lb-mole
379 ft^3 is the standard cubic feet per lb-mole at standard conditions
V = volume, cubic feet

However, the actual saturation rate depends on a variety of factors including temperature, agitation and time. For example, a completely filled fixed roof gasoline tank quickly drained would have a lower saturation rate compared to the same tank that was near empty when drained. Another factor complicating the ideal gas law methodology is sludge and product residue remaining in the tank when degassing commences. Additional hydrocarbon vapors are released from the sludge and residue while the tank is degassed.

In order to get a clearer picture of actual emissions being generated from tank degassing operations, 56 degassing logs were reviewed (see Appendix A). The logs indicate that there are fewer emissions in the storage tanks than the ideal gas law methodology would suggest. The actual emissions coming from tank degassing are 69 percent of the expected emissions using the ideal gas methodology. While most tanks have initial vapor concentrations greater than 100 percent LEL (roughly 50,000 ppmv, measured as methane), this is well below complete saturation. A possible explanation is that the tanks are drained faster than the liquid can evaporate. Once drained, degassing operations take place sooner than sludge and product residual can saturate the vapor space. Thus where the ideal gas law methodology would expect complete saturation, only partial saturation is seen. There may also be some unquantifiable loss when the contents of the tank are being pumped out of the tank. Vapor may be inadvertently removed if some part of the vacuum hose is above the liquid level.

Additionally, the degassing logs show that sludge and product residual significantly contribute to the emissions emanating from the storage tanks. A tank with partial saturation should be able to degas in a shorter time period than a completely saturated tank. However, the logs indicate that degassing actually takes a much longer time. On average, it takes two to three times longer because product residual and sludge continue to release vapors into the tank being degassed.

In the example provided in Table 3, a sample degassing log is examined. A floating roof gasoline tank with a vapor space of 7,921 cubic feet (59,249 gallons) is to be degassed. To comply with the current regulation, the company must degas at least 18,218 cubic feet of volume. The initial inlet concentration (150 percent LEL) is well below complete saturation used for an ideal gas calculation (approximately 600 percent LEL). After just over two hours, 2.3 air exchanges has been surpassed with an associated 149 pounds of VOC reduced. However, at least that much more remains in the tank and is not controlled until the inlet concentration is reduced below ten percent LEL. In the example tank, the emission reduction at 2.3 air

exchanges is approximately 40 percent and the actual emissions are about 74 percent of the expected emissions.

Table 3 - Degassing Log Example

Gasoline Tank Example
Volume to be Degassed: 7921 cubic feet
Expected Emissions: 502 pounds of VOC

Time	Flow from tank (cfm)	Cumulative Volume (cubic feet)	Inlet Concentration (% LEL)	Hourly emissions (pounds)	Cumulative Emissions (pounds)
1345	100	0	150	0.0	0.0
1400	200	1500	125	5.7	5.7
1500	700	13500	100	37.7	43.3
1600	800	55500*	76	105.5	148.8
1700	1000	103500	48	91.6	240.5
1800	1000	163500	21	72.3	312.8
1900	2100	223500	9	31.6	344.5
2000	2100	349500	7	28.5	372.9

*2.3 Air Exchanges Surpassed

Expected	2.3 Air Exchanges	Actual
502.0	148.8	372.9

Closer examination of individual tank logs reveal a wide variation in the actual emissions degassed from the tank. Some tanks have emissions much lower than expected suggesting a tank relatively free of sludge and product residual that was full to begin with and drained quickly. Others have emissions greater than expected probably because there was a larger vapor space that had time to reach equilibrium and/or significant amounts of sludge and product residual that continued to evaporate while the tank was being degassed. Theoretically, 2.3 air exchanges should reduce emission by 90 percent but the logs indicate an actual reduction rate of only 37 percent.

Using the notification data information and comparing the ratios of expected versus actual and expected versus 2.3 air exchanges we can determine how many pounds of emission can be captured by adopting a vapor concentration standard and comparing it to amount of emissions captured by the current standard of 2.3 air exchanges (see Table 4).

Table 4 – Emission Inventory Comparison

	Uncontrolled	2.3 Air Turnovers	Remaining
Total emissions using ideal gas law (tpd)	2.1	1.9	0.2
Total emissions from degassing logs (tpd)	1.4	0.5	0.9

Comparing the two methods to calculate emission inventory shows that the there is a smaller overall inventory using emissions from degassing logs. However, more emissions reductions can be realized by further restrictions in the rule, particularly by the establishment of a vapor concentration standard.

In addition to the already regulated ASTs and USTs, the proposed rule amendment would lower the tank capacity and vapor pressures subject to the regulation. ASTs of capacities of 500 gallons or greater containing gasoline would be subject to the rule. The 100,000 liter (26,420 gallon) tanks or greater containing crude oil or other products with Reid vapor pressure greater than 134 mm Hg (2.6 psi) would now be subject to the rule. And any tank larger than 378,500 liters (100,000 gallons) containing a product with a Reid vapor pressure greater than 25 mm Hg (0.5 psia) would be subject to Rule 1149.

Survey data and tank rosters provided by major refiners indicate that approximately 470 new tanks would be subject to the rule. The average capacity of the newly applicable tanks reported by the refiners is 2.5 million gallons. The average of the newly applicable tanks at terminals and other locations is 2.2 million gallons. The overall average for newly applicable tanks is 2.3 million gallons. In comparison, the average size of already applicable tanks is 5.5 million gallons or nearly double the volume of the newly applicable tanks.

Using the actual tank capacities and product contents from those refiners who provided the survey data, the average uncontrolled degassing emission from a newly applicable tank is 2,370 pounds of VOC. Applying the same correction factor of actual versus expected emissions (0.685) seen from the degassing logs summarized in Table 3, there would be 1,620 pounds of uncontrolled emission from degassing each newly applicable tank. Conservatively assuming that the tanks are degassed once every ten years, the annual uncontrolled emissions from newly applicable tanks would be 76,140 pounds (0.1 tons per day).

Aside from storage tanks, pipelines containing crude oil and gasoline would also be subject to the rule. According to the California Office of the State Fire Marshall, there are 7,500 miles (approximately 4,000 miles in the South Coast Air Basin) of hazardous liquid transportation pipeline within the state. California laws mandate that each pipeline system be tested at least every five years. Testing usually consists of hydrotesting or use of internal inspection tools sometimes known as “smart pigs”. Most pipeline inspection and repair activities already vent vapors to an uncontrolled vacuum truck. The result is 4.2 million cubic feet annually of gasoline or crude oil vapor could be released to the atmosphere. The proposed rule would apply to pipelines outside of permitted facilities that were six inches or greater in diameter. Pipelines shorter than 100 feet in length are exempt as are pipelines shorter than 0.25 miles containing or previously containing VOC liquids having a Reid vapor pressure less than 202 mm Hg. Staff estimates the addition of pipelines to the proposed rule adds 0.4 tons per day to the emission inventory.

In the 1987 rule underground storage tanks (USTs) originally contributed 0.63 tons per day to the uncontrolled emission inventory and the rule was expected to reduce 0.3 tons per day. In 1995, the staff report indicated that the number of USTs had decreased by 70 percent. However, emission calculations in the 1995 Final Staff Report for Proposed Amended Rule 1149 – Storage Tank Degassing show that the emission reductions remained the same because emissions from USTs were higher than originally estimated and industry practices now reduced emissions by 99

percent. Over the past three years, an average of 501 USTs were degassed with an average capacity of 11,346 gallons. The uncontrolled emissions from USTs were 0.07 tons per day calculated by adjusting the number of tanks and average volume in comparison to estimates made in previous staff reports. Using the 99 percent control efficiency claimed by the 1995 rule amendment, the emission reduction from USTs were also 0.07 tons per day. No emission reductions from USTs are claimed in this proposed amendment. In summary, the total uncontrolled emissions from all sources subject to the proposed amendments to Rule 1149 is 1.97 tons per day with 0.57 tons per day controlled by existing regulations (see Table 5). Therefore the remaining emission inventory to be further regulated by the proposed amendments to Rule 1149 is 1.4 tons per day of VOC.

Table 5 – Emission Inventory from All Rule 1149 Sources

Source	Emissions Inventory Before Control	Emissions Controlled by Existing Rule 1149	Remaining Emissions Inventory
ASTs currently subject to rule (tpd)	1.4	0.5	0.9
USTs (tpd)	0.07	0.07	0
Newly applicable ASTs (tpd)	0.1	0	0.1
Pipelines (tpd)	0.4	0	0.4
Total emissions from all Rule 1149 Sources (tpd)	**1.97**	**0.57**	**1.4**

EMISSION REDUCTIONS

The proposed rule amendment would set a vapor concentration limit of 5,000 ppmv on tanks and pipelines subject to the rule. Connections, hoses, and vacuum trucks would also be required to keep emissions below 5,000 ppmv. Control devices would not be required by the regulation. Alternative methods such as routing the exhaust to other tanks, applying chemicals or water to reduce vapors or any other means to reduce the tank or pipeline concentration would be allowed so long as hydrocarbon vapors with a concentration greater than 5,000 ppmv were not allowed to be vented to atmosphere. Control devices used to reduce the vapors in tanks and pipelines would be limited to an exhaust concentration of 500 ppmv, which is consistent with other AQMD rules.

A limit of 5,000 ppmv captures an estimated 90 percent or more of the remaining emissions. Utilizing the degassing logs, a comparison can be made between the quantity of emission captured when the 5,000 ppmv standard is reached and the total quantity of emissions in the storage tank. Reviewing the example in Table 3, almost 97 percent of emissions are captured when degassing to 5,000 ppmv (roughly ten percent LEL). Reviewing all of the storage tanks that met or exceeded the standard, a limit of 5,000 ppmv captures between 86.3 percent and 99.7 percent of emissions from tanks. The average emission reduction is 95.8 percent.

Adoption of a vapor concentration standard of 5,000 ppmv will reduce emissions from existing and newly applicable sources by at least 90 percent. The total annual uncontrolled VOC emissions from existing and newly applicable sources are 1.97 tons per day. The current provisions in the rule already reduce 0.57 tons per day of the uncontrolled VOC emissions. The

proposed rule amendments will reduce VOC emissions by another 1.25 tons per day calculated based on the practice of degassing to 5,000 ppmv (see Table 6). Further controlling vacuum trucks used to remove residual product and sludge, requiring residual product and sludge to held in closed containers that are free of liquid and vapor leaks and establishing a vapor concentration requirement for control devices will limit fugitive emission losses.

Table 6 – Emission Reductions from All Rule 1149 Sources

Source	Emission Inventory	Emissions Controlled by Existing Rule 1149	Remaining Emissions Inventory	Emissions Controlled by Proposed Rule
ASTs currently subject to rule (tpd)	1.4	0.5	0.9	0.8
USTs (tpd)	0.07	0.07	0	0
Newly applicable ASTs (tpd)	0.1	0	0.1	0.09
Pipelines (tpd)	0.4	0	0.4	0.36
Total emissions from all Rule 1149 sources (tpd)	**1.97**	**0.57**	**1.4**	**1.25**

Along with reductions in VOC emissions from the proposed provisions of this rule, there would also be some increases in criteria pollutants because of increased use of control equipment. Except in the limited circumstances where liquid balancing is used, the primary methods of control are absorption onto carbon or oxidation using internal combustion engines and thermal oxidizers. Conservatively, it is assumed that all new sources will be controlled using either an internal combustion engine or thermal oxidizer. Undoubtedly, some sources will use liquid balancing and other technologies or degassing methods may be developed which do not require combustion.

Over the past three years, 47.9 million cubic feet of tank space was degassed on average annually. Based on this average and the calculated average cubic feet degassed per gallon of propane, 35,143 gallons of propane are used to degas storage tanks each year. The proposed rule would increase the usage of propane by nearly seven times for tanks already subject to the rule. Additionally, another 7.0 million cubic feet of degassing would be necessary with the proposed pipeline and smaller/low vapor pressure tanks requirements. The total average amount of degassing would increase to 54.9 million cubic feet annually. The total propane usage would increase to 277,273 gallons annually. SCAQMD default emission factors for criteria pollutants and U.S. Department of Energy, Energy Information Administration factors for carbon dioxide emissions were used to calculate pollutant emissions. The ratio of thermal oxidizer use (69 percent) to internal combustion engine use (31 percent) was determined from notification data. The average daily increase in criteria pollutants and greenhouse gas emissions are calculated below:

Table 7 – Related Increase in Criteria Pollutants and Greenhouse Gas Emissions

Current	NOx (annual lbs)	VOC (annual lbs)	SOx (annual lbs)	CO (annual lbs)	CO2 (annual lbs)	Methane (annual lbs)	PM (annual lbs)
at 100% thermal oxidizer use	450	9	162	112	445,227	10	10
at 100% IC engine use	4,885	2,917	12	4,533	445,227	0	176
at 69%/31% T.O./ICE use	1,816	905	116	1,474	445,227	7	61

Proposed	NOx (annual lbs)	VOC (annual lbs)	SOx (annual lbs)	CO (annual lbs)	CO2 (annual lbs)	Methane (annual lbs)	PM (annual lbs)
at 100% thermal oxidizer use	3,550	72	1,275	887	3,512,341	78	78
at 100% IC engine use	38,541	23,011	97	35,764	3,512,341	0	1386
at 69%/31% T.O./ICE use	14,327	7,137	912	11,629	3,512,341	54	481

	NOx	VOC	SOx	CO	CO2	Methane	PM
Daily increase (pounds)	34	17	2	28	8,403	0	1

COST AND COST-EFFECTIVENESS

Currently, nearly all USTs and some ASTs are already degassed to meet the 5,000 ppmv limit. For those operations that currently meet only the 2.3 air exchange standard, it is calculated that it will take 2.8 times longer to degas a tank to the proposed limit (see Appendix B).

For already applicable ASTs, degassing companies generally charge between $2,000 and $20,000 to degas tanks. For an average sized tank, a typical cost would be approximately $10,000 with $2,000 a flat fee and the remainder based on an hourly rate. On average, a typical storage tank takes about eight hours to degas to the current rule requirement of 2.3 air exchanges. To reach the proposed concentration limit, it is estimated that it will take 24.1 hours. This hourly increase of 180 percent would add $14,680 per operation. For the 328 existing operations annually, the cost increase would be $4.8 million dollars.

Already applicable ASTs

Currently: $2,000 + 8.5 hours * $941/hr = $10,000

Proposed: $2,000 + 24.1 hours * $941/hr = $24,680 (a $14,680 increase)

Annual Cost Increase: $14,680/operation * 328 operations = $4.8 million

For the 470 newly applicable ASTs and again assuming that they are degassed once every ten years, 47 newly applicable tanks would be degassed. However, because the newly applicable tanks are 58 percent smaller, based on survey data and tank rosters, and have 51 percent lower vapor concentration, because of the lower vapor pressure products previously contained within, they could be degassed at 30 percent of the cost or $7,400. At a cost of $7,400 each, the 47 newly applicable tanks degassed annually would do so at an annual cost of $0.3 million dollars.

Newly applicable ASTs

Newly applicable AST = 24.1 hours * 0.58 volume * 0.51 vapor concentration = 7.1 hours

Proposed: $2,000 + 7.1 hours * $941/hr = $8,700

Annual Cost Increase: $8,700/operation * 47 operations = $0.4 million

Requiring vacuum trucks to vent vapors to a control device such as a carbon canister during pipeline degassing would increase the cost by $500 to $4,000 per operation according to contractors who offer those services. An ordinary operation may displace between one mile and 30 miles of pipeline. Eight hundred miles of pipeline need to be maintained annually. At an average of five miles, 160 pipeline degassing operations would be necessary annually. At $2,000 per operation, the total annual cost increase to control pipeline degassing would be $0.3 million dollars.

Newly applicable pipelines

Annual Cost Increase: $2,000/operation * 160 operations = $0.3 million

For USTs, degassing companies charge between $600 and $1,000 to degas a tank. Because virtually all are already meeting the proposed limit, they would not need to change their operations or charge more to their customers.

As proposed, the rule would reduce emissions by 1.25 tons per day with an estimated cost of $5.5 million dollars. The overall cost per ton reduced by the proposed amendment would be $12,055 (see Table 8).

Table 8 - Cost Effectiveness Summary

Emission Source	Emissions before control	Emissions controlled by existing regulations	Emissions controlled by proposed rule	Estimated Cost
ASTs currently subject to Rule 1149 (tpd)	1.4	0.5	0.8	$4,800,000
USTs (tpd)	0.07	0.07	0	$0
Newly applicable ASTs (tpd)	0.1	0	0.09	$400,000
Pipeline (tpd)	0.4	0	0.36	$300,000
Total emissions from all Rule 1149 Sources (tpd)	1.97	0.57	1.25	$5,500,000
Cost Effectiveness			**$12,055**	

INCREMENTAL COST-EFFECTIVENESS

Under Health and Safety Code Section 40920.6, the AQMD is required to perform an incremental cost analysis when adopting a Best Available Retrofit Control Technology (BARCT) rule or feasible measure required by the California Clean Air Act. To perform this analysis, the AQMD must (1) identify one or more control options achieving the emission

reduction objectives for the proposed rule, (2) determine the cost effectiveness for each option, and (3) calculate the incremental cost effectiveness for each option. To determine incremental costs, the AQMD must "calculate the difference in the dollar costs divided by the difference in the emission reduction potentials between each progressively more stringent potential control option as compared to the next less expensive control option."

Proposed Amended Rule 1149 implements Control Measure Fug-04 from the 2007 Air Quality Management Plan. Because Control Measure Fug-04 is intended to meet feasible measure requirements under the California Clean Air Act, an incremental cost analysis is required.

Several alternative options were evaluated including one less stringent standard and two more stringent standards. The first alternative examined was to increase the number of air exchanges required from 2.3 as is currently required in the rule, to 4.6 air exchanges. Theoretically this would raise the control efficiency of the rule from 90 percent to 99 percent. However, as discussed above, 2.3 air exchanges only achieves 37 percent control efficiency. From review of the degassing logs, it is estimated that emission reductions would increase to approximately 55 percent control efficiency. This would be well below the 90 percent control efficiency expected by the current proposal and reduce only 0.8 tons per day of VOC emissions. While the overall cost would be lower ($4.1 million), the cost effectiveness would be rise to $14,041 per ton of VOC reduced.

A small number of the degassing logs reviewed indicate that those tanks were degassed well below the proposed limit. From those logs, we can estimate that decreasing the proposed limit from 5,000 ppmv to 3,500 ppmv would increase the average cost of the operation by 202 percent and lowering the limit even further to 2,000 ppmv would increase the average cost by 221 percent resulting in incremental cost effectiveness of $273,973 and $684,932 per additional ton of VOC reduced, respectively. The large increase in incremental cost is due primarily to the very small additional emission reductions realized from lowering the proposed vapor concentration limit.

Table 9 – Cost Effectiveness by Vapor Concentration Limit

PPM limit	Emission reductions (tons per day)	Average Additional Hours Per Tank	Annual Additional Cost (million)	Incremental Cost Effectiveness (Cost/Additional Ton
5,000	1.25	15.6	$5.5	$5,479
3,500	1.256	17.5	$6.0	$273,973
2,000	1.258	19.2	$6.6	$684,932
4.6 air exchanges	0.8	13.0	$4.1	N/A

COMPARATIVE ANALYSIS

Health and Safety Code Section 40727.2 requires a written analysis comparing the proposed rule with existing regulations. Federal regulations do not require control of vapors from degassing operations but 40 CFR Part 280 does require underground storage

tanks to be empty before removal. No other AQMD regulations apply to storage tank or pipeline degassing.

SOCIOECONOMIC ASSESSMENT

A socioeconomic analysis of the amendments to Rule 1149 will be performed. A draft report will be released no later than 30 days prior to the AQMD Governing Board hearing.

CALIFORNIA ENVIRONMENTAL QUALITY ACT (CEQA)

Pursuant to the California Environmental Quality Act (CEQA) and AQMD Rule 110, appropriate documentation will be prepared to analyze any potential adverse environmental impacts associated with the proposed amendments to Rule 1149. Comments received at the public workshop and CEQA scoping meeting will be considered when preparing the CEQA document.

DRAFT FINDINGS UNDER THE CALIFORNIA HEALTH AND SAFETY CODE

Health and Safety Code Section 40727 requires that prior to adopting, amending or repealing a rule or regulation, the AQMD Governing Board shall make findings of necessity, authority, clarity, consistency, non-duplication, and reference based on relevant information presented at the hearing. The draft findings are as follows:

Necessity – State and federal health-based ambient air quality standards for ozone are regularly and significantly violated in the AQMD. The reduction of VOC from the proposed amendments to Rule 1149 is part of a comprehensive strategy to meet federal and State air quality standards.

Authority - The AQMD Governing Board obtains its authority to adopt, amend, or repeal rules and regulations from Health and Safety Code Sections 39002, 40000, 40001, 40440, 40441, 40702, 41508, and 41700.

Clarity - The AQMD Governing Board has determined that the proposed amendments to Rule 1149 – Storage Tank and Pipeline Cleaning and Degassing, are written and displayed so that the meaning can be easily understood by persons directly affected by them.

Consistency - The AQMD Governing Board has determined that Proposed Amended Rule 1149 – Storage Tank and Pipeline Cleaning and Degassing, is in harmony with, and not in conflict with or contradictory to, existing statutes, court decisions, federal or state regulations.

Non-Duplication - The AQMD Governing Board has determined that the proposed amendments to Rule 1149 – Storage Tank and Pipeline Cleaning and Degassing, do not impose the same requirement as any existing state or federal regulation, and the proposed amendments are necessary and proper to execute the powers and duties granted to, and imposed upon, the AQMD.

Reference - In adopting this regulation, the AQMD Governing Board references the following statutes which the AQMD hereby implements, interprets or makes specific: California Health and Safety Code sections 40001, 40440, and 40702.

REFERENCES

California Office of the State Fire Marshall. 2006. Pipeline Safety Program web site.

California Energy Commission. April 2003. *California Marine Petroleum Infrastructure*.

San Joaquin Valley Unified Air Pollution Control District. March 2005. Final Draft Staff Report for Proposed Amendments to Rule 4623 (Storage of Organic Liquids).

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SCAQMD. June 1995. Final Staff Report for Proposed Amended Rule 1149 – Storage Tank Degassing.

Sung, Hung-Ming (Sue). Trinity Consultants. July 2004. *Testing VOC Evaporation Losses from Floating Roof Tank Turnovers*.

U.S. EPA. September 2006. *Emission Factor Documentation for AP-42, Section 7.1, Organic Liquid Storage Tanks*.

Appendix A – Tank Degassing Logs

In Appendix A, the volume refers to amount of cubic feet in the tank needed to be degassed. The expected emissions are calculated from the ideal gas law methodology for the volume and product contained in the tank. The actual emissions are taken from the tank degassing logs and reflect the total pounds of VOC controlled before the operation was stopped. The actual emissions when 2.3 Q was reached is the amount of pounds of VOC controlled when the current Rule 1149 requirement of 2.3 air exchanges was met. Emissions from the degassing logs are calculated by determining the vapor concentration going into the control device and then determining the hourly pounds of emission controlled as the flow and vapor concentration change over time. In addition to other information, the degassing logs note the air flow from the tank, the vapor concentration from the tank, the air flow going into the control device and the time.

Vapor concentration to the control device is calculated by multiplying the inlet vapor concentration from tank to ratio of the air flow from the tank over the overall air flow into the control device.

$E = (C * M * F * T) / (V * 1{,}000{,}000)$

where:

E = emissions, lb
C = concentration of vapor going into the control device, ppmv
M = molecular weight of vapor, lb/lb-mole
F = air flow to control device, cfm
T = time, minutes
V = molar volume

and $C = I * (A / F)$

where:

C = concentration of vapor going into the control device, ppmv
I = concentration of vapor from the storage tank, ppmv
A = air flow from the storage tank, cfm
F = air flow to control device, cfm

Tank	Capacity (cubic feet)	Expected emissions from ideal gas law (lb)	Actual emissions reduced from degassing logs (lb)	Actual emissions reduced from degassing logs when 2.3 Q reached (lb)	Product	Actual vs. Expected	2.3 Q vs. Expected
1	106,029	6,729	1,988	824	Gasoline	29.54%	12.25%
2	22,620	402	1,476	280	Sour Naphtha	367.16%	69.65%
3	44,872	2,848	253	102	Gasoline	8.90%	3.59%
4	21,154	376	2,670	224	Sour Naphtha	710.11%	59.57%
5	83,095	2,983	95	81	Sour Water	3.18%	2.72%
6	11,133	706	279	100	Gasoline	39.52%	14.16%
7	7,921	502	346	177	Gasoline	68.93%	35.28%

8	40,212	2,552	5,322	1,856	Isomerate	208.54%	72.73%
9	15,708	997	404	266	Isomerate	40.48%	26.67%
10	83,095	5274	197	184	Gasoline	3.74%	3.49%
11	76,027	4790	1,521	1,163	Gasoline	31.75%	24.27%
12	157,284	9909	2,209	1,654	Gasoline	22.29%	16.69%
13	114,512	7214	4,309	2,850	Gasoline	59.73%	39.51%
14	56,143	3537	11,592	1,760	Gasoline	327.72%	49.77%
15	90,478	5700	525	266	Gasoline	9.21%	4.66%
16	95,108	5992	2,691	2,662	Gasoline	44.92%	44.43%
17	16,964	609	1,720	100	Gasoline	282.45%	16.45%
18	75,218	4739	5,775	466	Gasoline	121.86%	9.84%
19	28,066	774	731	189	Gasoline	94.44%	24.40%
20	1,257	80	100	64	Transmix	125.45%	79.65%
21	15,708	997	14	14	Sour Naphtha	1.38%	1.38%
22	6,597	733	17	15	Brine Water	2.28%	2.10%
23	153,726	5518	1,627	588	Alkylate	29.49%	10.66%
24	50,894	840	247	172	Ethanol	29.43%	20.48%
25	11,133	183	220	145	Ethanol	120.08%	79.21%
26	80,000	2,872	1,690	1,266	Crude Oil	58.84%	44.08%
27	55,000	1,974	462	Not reported	Crude Oil	23.40%	21.06%
28	40,000	1,436	952	Not reported	Crude Oil	66.30%	59.67%
29	76,440	5,104	2,969	499	Gasoline	58.17%	9.77%
30	21,434	2,384	6,177	1,007	Gasoline	259.10%	42.24%
31	73,054	6,153	4,376	3,630	Gasoline	71.12%	59.00%
32	49,055	4,162	10,416	1,849	Gasoline	250.26%	44.43%
33	45,454	2,885	950	844	Gasoline	32.93%	29.25%
34	50,802	3224	821	736	Gasoline	25.46%	22.83%
35	113,636	7,212	1,361	1,361	Gasoline	18.88%	18.88%
36	13,369	848	1,598	289	Gasoline	188.44%	34.12%
37	50,802	3,224	234	234	Gasoline	7.25%	7.25%
38	40,107	254	34	34	Naphtha	13.44%	13.44%
39	46,791	766	114	114	Alkylate	14.91%	14.91%
40	46,791	766	209	186	Alkylate	27.34%	24.32%
41	46,791	766	490	239	Alkylate	64.03%	31.23%
42	46,791	766	220	198	Alkylate	28.66%	25.86%
43	16,956	1,076	245	125	Gasoline	22.75%	11.62%
44	11,775	747	191	79	Gasoline	25.59%	10.61%
45	105,975	6,726	1,242	927	Gasoline	18.46%	13.78%
46	105,975	6,726	2,472	881	Gasoline	36.75%	13.10%
47	11,775	747	206	193	Gasoline	27.52%	25.87%
48	21,143	60	99	99	Ethanol	164.79%	164.79%
49	13,734	871	203	174	Gasoline	23.33%	19.98%
50	11,775	77	40	40	Ethanol	51.91%	51.91%
51	40,107	144	66	57	Transmix	46.00%	39.47%
52	16,956	608	19	13	Transmix	3.12%	2.21%
53	65,582	4162.4	10,417	1,849	Gasoline	250.26%	44.42%
54	97,667	6199	4,376	3,630	Gasoline	70.60%	58.56%
55	28,656	1028	6,177	1,007	Crude Oil	600.88%	97.97%
56	113,636	7,212	1,815	1,742	Gasoline	25.17%	24.15%
Total	2,942,983	156,163	106,969	39,506	all (total)	68.50%	25.30%

Appendix B – Time to Complete Degassing

The information in Appendix B was evaluated to determine the increase in time required to meet the proposed vapor concentration limit of 5,000 ppmv. Various degassing contractors submitted degassing logs for tanks they had degassed over the previous year. The tanks listed met the criteria that they both were degassed until the current rule requirement of 2.3 air exchanges was met and degassed until the proposed rule requirement of 5,000 ppmv (ten percent LEL) was met.

Not all tanks met the dual criteria and those that did not were not included. The average times to reach 2.3 air exchange and the proposed concentration limit were calculated and are used to determine how much longer, on average, it will take to degas tanks to the new standard. This information is used to calculate both increased costs and increased secondary emissions created from associated control equipment such as internal combustion engines and thermal oxidizers.

Tank	Time to Reach 2.3 Air Exchanges (hours)	Time to Reach Proposed Concentration Limit (hours)
A2	3	11
A3	6	22
A4	3	20
A5	2	3
A6	2	7
A7	1	4
A8	6	34
B1	4	7
B2	3	4
B3	7.5	12.5
B4	10	17
B6	8	18
B8	7	7
B9	13	23
B10	2	8
B11	4	23
B12	2	16
B14	1	4
B15	1	1
B16	4	9.5
B17	1	2
B19	5	11
B20	1	3
B22	11	40
C1	45	57
C2	13	74
C3	20	127
D1	8	5
D2	3.5	5
D3	6	4.5
Total (hrs)	203	579.5
Average (hrs)	8.5	24.1